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US Army Research Laboratory

Achieving 5-µs Simultaneity of 36 RP-80 Detonators

by Barry L Hudler, Eric W Miller, and Jarid M Kranz

NOTICES

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14. ABSTRACT

The US Army Research Laboratory investigated the conditions and the materiel required to fire large numbers of RP-80 detonators simultaneously using the FS-43 firing system. The results of the investigation demonstrated an in-house capability for initiating 36 detonators within a 5-μs simultaneity interval.

15. SUBJECT TERMS

multiple detonators, FS-43, RP-80, simultaneous detonation, firing system

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1. Introduction

Experiments were recently conducted at the US Army Research Laboratory (ARL) Transonic Experimental Facility (TEF) in which 36 RP-80 detonators were initiated in a 5-μs interval. The experiments were conducted in support of modular lethality studies within ARL's Scalable Effects Program. The 5-μs simultaneity interval was established as a requirement to avoid predetonation interference between adjacent Comp B modular charges and was based on the expected travel times of the detonation wave fronts.

Preliminary discussions with scientists, engineers, and technicians within ARL indicated that previous in-house experiences with simultaneous detonation experiments consisted of, at most, several detonators. As such, the initiation circuit for 36 detonators represented a novel in-house application, possibly with complexity and constraint beyond that of a circuit for several detonators. To establish a level of reliability in the 36-detonator initiation circuit and to verify that the spontaneity and non-interference requirements were being satisfied, a series of detonator-only experiments was conducted. The detonator-only experiments preceded a successful simultaneous detonation of 33 Comp B modular charges in close proximity.

This technical note describes details and results of the detonator-only experiments, with focus on the detonator initiation circuit and associated considerations. Notable aspects of the initiation circuit configuration and performance are described that may serve as a useful reference for future simultaneous detonation experiments.

2. Background

RP-80 detonator initiation has been performed at TEF and other ARL experimental facilities for many years. At TEF, the typical experimental application involving detonation initiation uses a RISI FS-43 firing system (which consists of a control unit and a firing module) and 1 or 2 RISI RP-80 exploding bridge wire (EBW) detonators. Appendixes A and B are manufacturer's information sheets on the FS-43 and RP-80, respectively. The RISI FS-43 uses a low-voltage 3-pair wire as the permanent firing line (from control unit to firing module). The initiation circuit for ARL in-house detonation experiments follows a baseline configuration as prescribed in ARL Standard Operating Procedure (SOP) 385-008.[1]

Figure 1 is a copy of illustration 3 from SOP 385-008 that shows the transfer box configuration (in the "safe" position) between the FS-43 control unit and a single RP-80 detonator. The transfer box contains the FS-43 firing module and 3 knife switches. The transfer box is typically located within an uninhabited bombproof or behind a barricade in close proximity to the explosive event, while allowing the control unit to be emplaced at the operator location much farther away. This configuration represents that which was used for shot 1 in the firing matrix for a single detonator. (Important note: Approved initiation circuits at ARL for intentional detonations include the RISI FS-43 and Cordin Model 640 High Energy Pulser. Information contained in this report will *not* correlate to multiple detonator use with the Cordin model.)

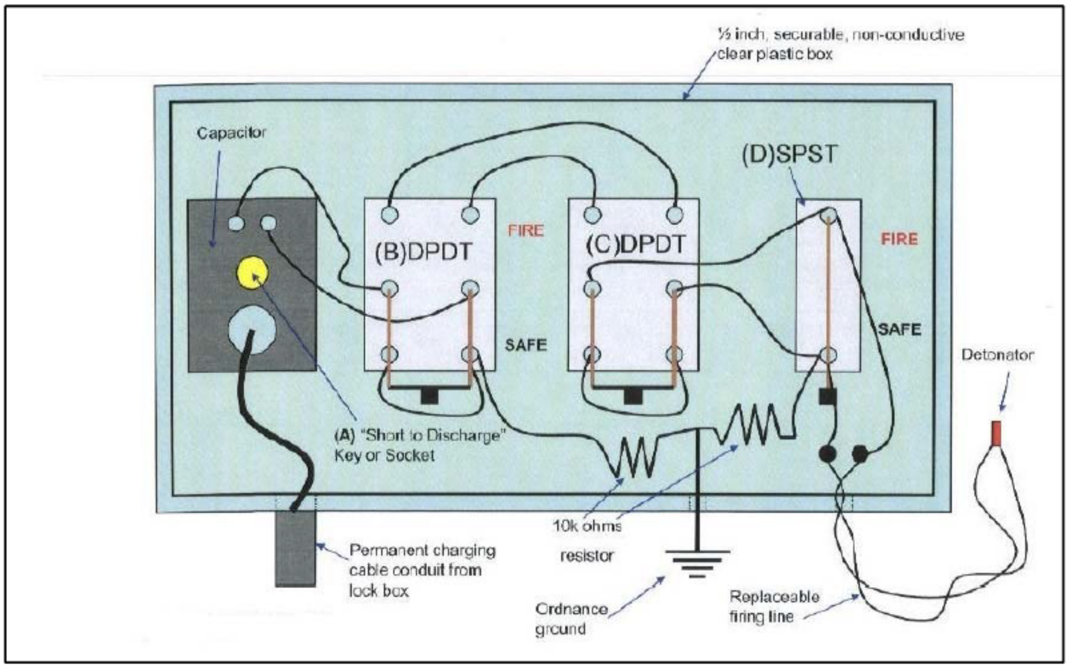

Fig. 1 Transfer box configuration for one FS-43 firing system and one RP-80 detonator (shot 1)

Basic considerations for this experiment included firing line length and type, both of which affect the rise time of the applied voltage. With a proper rise time (less than 3 μs), RP-80s can be expected to fail at a rate of 1 in 1,000. A rise time greater than 3 μs can be expected to produce a significantly higher detonator failure rate.

Technical representatives from Teledyne RISI Inc. (manufacturer/supplier of the FS-43 firing systems and RP-80 EBW detonators) were contacted to obtain information and insight regarding multiple-detonator applications using their products. They supplied a standard 1-page information sheet entitled "Series Parallel Firing of EBW Detonators", which is included herein as Appendix C. The information sheet included a chart showing the recommended maximum number of RP-80 detonators that can be reliably initiated on each leg of a series-parallel circuit using the FS-43 firing system, as well as some precautionary recommendations.

The information sheet was used as a basis for initially determining some configuration options that could be expected to provide the necessary voltage and simultaneity for 36 detonators. For the experiments described herein, the length of the replaceable firing line between the transfer box and detonator(s) was firmly established as 50 ft. The configuration that was explored and eventually adopted for initiating 36 detonators was the use of 2 separate FS-43 systems, each providing initiation voltage for 18 detonators.

The information sheet was based upon certain materiel and/or conditions that were not duplicated in the actual experimental setup. For example, the length of blasting wire in the chart does not account for the presence of knife switches, which can introduce inductance as well as uncertain additional effective firing line length.

Another example of a condition not duplicated in the experimental setup was the type of replaceable firing line upon which the chart is based. The chart refers to RISI twin-lead blasting wire (part number 167-8559) and RISI "C" cable (part number 162-2669); whereas the experiments were begun using RG-58 multistrand coaxial wire and completed using Belden 8470-063 black and white (B/W) twisted pair of single, insulated, 16 American wire gauge (AWG) lines. Eventually, the B/W twisted pair wire was adopted and used to initiate the 33 RP-80 detonators for the full-up 33 Comp B module test.

Table 1 shows manufacturer-stated resistance and some physical properties of the 4 types of wire of interest. In addition to their resistance, the main differences in these 4 different types of firing lines are based upon their expense, ruggedness, and insulation. RISI C cable, the most expensive and most rugged, is used at 2 ARL facilities and in a tandem configuration for the Cordin system described above; it is also used at some ARL experimental facilities as a permanent, buried, conductor. B/W twisted pair, the least expensive and least rugged, is used almost exclusively as the firing line of choice at TEF. The other 2 types of wires are intermediate in terms of expense and ruggedness.

Table 1   Physical properties and resistance of firing lines of interest

Type	Diameter (inches)	AWG	Resistance per 1,000 ft (ohms)
RISI "C" coaxial cable	0.059 (center conductor)	~15	3.18
RISI twin lead blasting wire	0.032	20	10.15
RG-58 coaxial	0.032–0.037 (center conductor)	~20	11.9
B/W twisted pair	0.051	16	4.8

In-house discussions also revealed that the 5-μs spontaneity requirement for these experiments was less stringent than in some past in-house experiments using RP-80-class detonators. It was learned that, during such past experiments, simultaneity of less than 1 μs was achieved for 2 to 3 detonators. At that time, it was also concluded that multiple parallel legs with one detonator per leg provided a smaller simultaneity interval than one leg with multiple detonators in series. Other unique conditions associated with those past experiments (such as firing line lengths) may have contributed to the optimum circuit configurations that were adopted at that time.

3. Experimental Setup and Firing Matrix

To establish a level of reliability using the actual onsite materiel and conditions, a series of detonator-only experiments was conducted. Figure 2 shows a wooden fixture that was designed and constructed to hold multiple detonators in place. The fixture facilitated the connection of each detonator to the firing circuit, while providing a view for high-speed video coverage. The high-speed video would verify detonation and simultaneity for each shot. Figure 3 shows a view of the fixture with the camera bombproof in the background.

Fig. 2 Fixture used for detonator-only experiments

Fig. 3 View of fixture with camera bombproof in background

Table 2 shows the firing matrix that was executed for the detonator-only experiments. The original matrix was devised to incorporate increasing numbers of detonators and their simultaneity using small parameter changes. The eventual, final matrix was developed as the experiments progressed, based upon the observed results. The description of results to be presented subsequently describes pertinent outcomes of select shots. Five shots are marked as having failed (i.e., failed to satisfy the 5-μs simultaneity and/or non-interference criteria), and were especially valuable for identifying limiting aspects of the evolving initiation circuit.

Table 2   Experimental firing matrix

Date	Shot	TEF No.	Firing Systems	Wire Type	Firing Lines per Firing System	Dets per Firing Line	Total Number of Dets	Check if Failed
11/8/2013	1	39046	1	RG58	1	1	1	…
11/8/2013	2	39047	1	RG58	1	2	2	…
11/8/2013	3	39048	1	RG58	3	1	3	…
11/8/2013	4	39050	1	RG58	3	3	9	☑
11/8/2013	5	39051	1	RG58	3	3	9	☑
11/19/2013	6	39053	1	B/W	3	3	9	…
11/19/2013	7	39054	1	B/W	3	3	9	…
11/19/2013	8	39055	1	B/W	3	6	18	…
11/19/2013	9	39056	1	B/W	3	6	18	…
11/20/2013	10	39057	2	B/W	3	1	6	☑
11/20/2013	11	39058	2	B/W	3	1	6	☑
11/20/2013	12	39059	2	B/W	1	1	2	…
11/21/2013	13	39060	2	B/W	3	1	6	…
11/21/2013	14	39061	2	B/W	3	3	18	…
12/19/2013	15	39184	2	B/W	3	6	36	☑
12/19/2013	16	39185	2	B/W	3	6	36	…

A Phantom 7.3 high-speed digital video camera was used to observe the detonation events. Table 3 shows the camera settings for each shot. The 5-μs desired spontaneity interval represented a near-limit condition for this camera, and was achieved by reducing the field of view and image resolution. The resulting video images were adequate to determine the relative initiation times for each detonator, although the resolution was so low as to sometimes produce blurred or grainy images. The high-speed video camera was used, to an extent, as a sensor rather than a pure image recorder. Examples of video frames obtained for several shots are included with the subsequent discussion of results herein.

Table 3 High-speed camera settings at 1-μs exposure time

Shot	TEF No.	Total Number of Dets	Resolution (horizontal × vertical pixels)	Frame Interval (μs)	Frame Rate (frames per second)
1	39046	1			
2	39047	2	32 × 24	5	200,000
3	39048	3			
4	39050	9			
5	39051	9		9	111,111
6	39053	9			
7	39054	9			
8	39055	18			
9	39056	18			
10	39057	6	160 × 64		
11	39058	6		6.25	160,000
12	39059	2			
13	39060	6			
14	39061	18			
15	39184	36			
16	39185	36			

4. Experimental Results for a Single Firing System

Figure 4 shows 3 successive video frames capturing the initiation of shot 1, i.e., a single FS-43 firing system and one RP-80 detonator using RG58 wire. The camera interval was set to 5 μs and is adequate to show an intermediate stage of growth in the light produced by the detonator initiation.

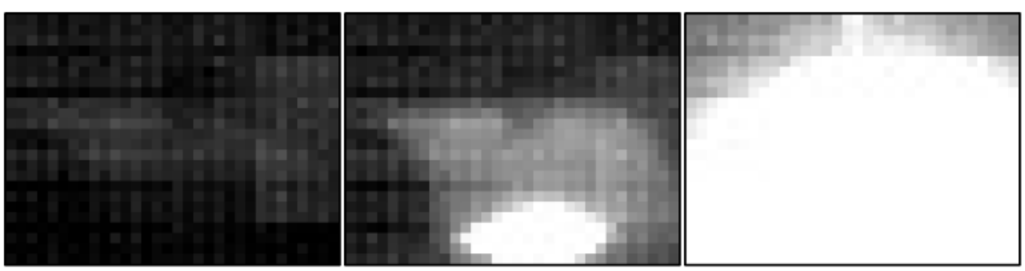

Fig. 4 Successive video frames for shot 1 at 0, 5, and 10 μs (left to right)

Figure 5 is a diagram of the transfer box configuration used for shot 2, i.e., for one FS-43 firing system and 2 RP-80 detonators in series on a single leg of RG58 wire. The length of firing line between adjacent detonators in series was several inches. This length was consistent with the length eventually used to connect, in series, 1-inch-thick, 2-inch-diameter Comp B modular charges in contact with each other. Figure 6 shows 3 successive 5-μs video frames capturing the initiation of shot 2, confirming that both detonators initiated within a 5-μs interval.

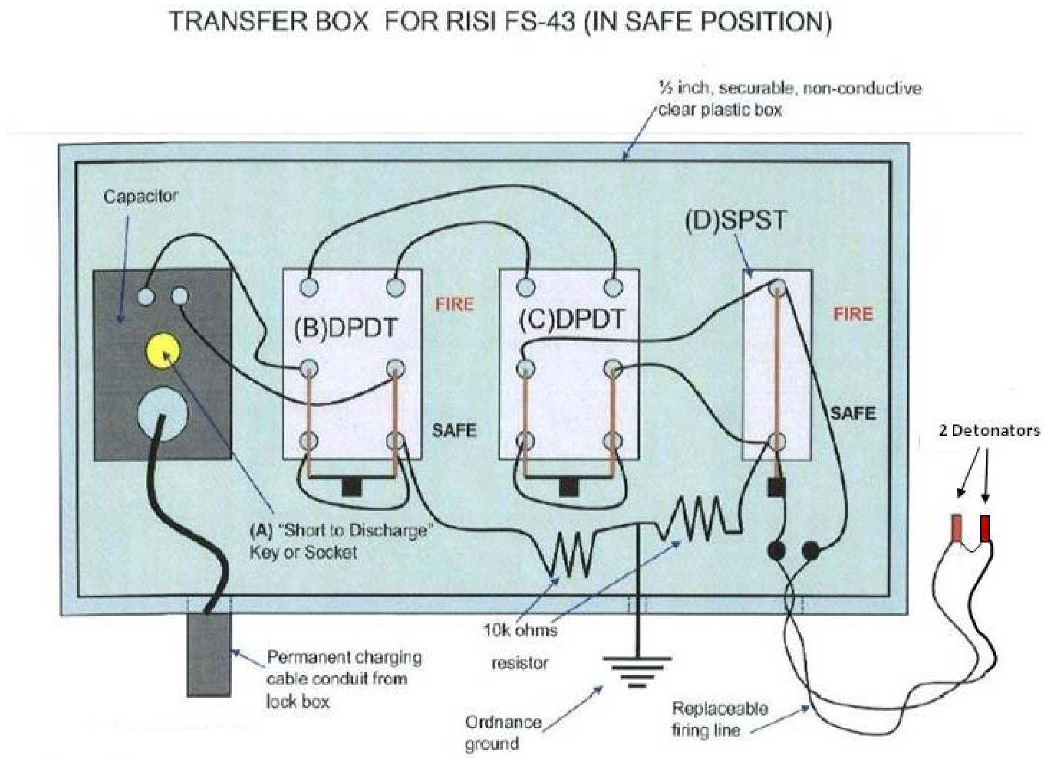

Fig. 5 Transfer box configuration for shot 2

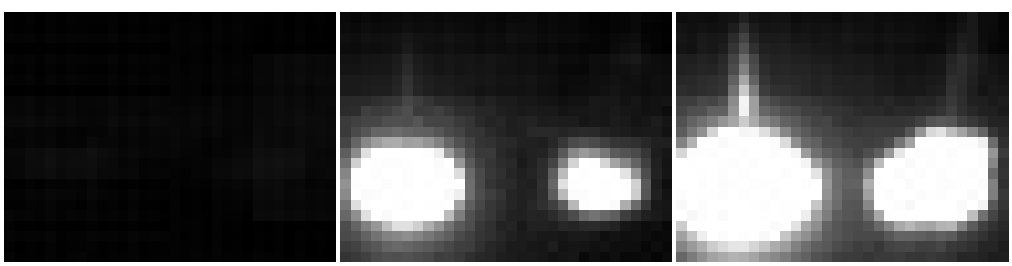

Fig. 6 Successive video frames for shot 2 at 0, 5, and 10 μs (left to right)

Figure 7 is a diagram of the transfer box configuration used for shot 3, i.e., using one FS-43 firing system and 3 RP-80 detonators, each connected to a parallel leg of RG58 wire. Figure 8 shows 3 successive 5-μs video frames demonstrating that all 3 detonators initiated within a 5-μs interval.

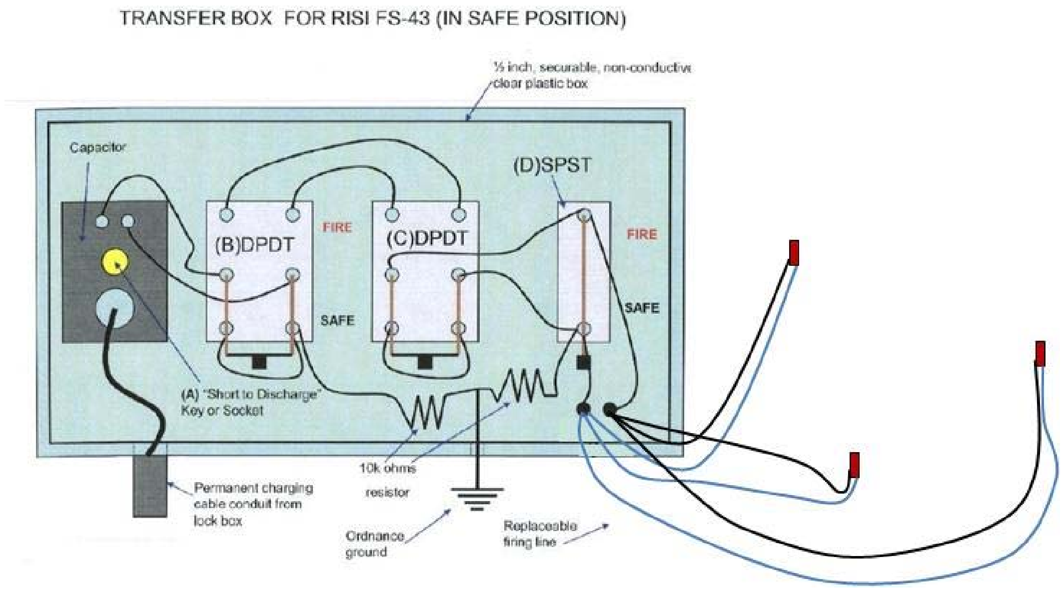

Fig. 7 Transfer box configuration for shot 3

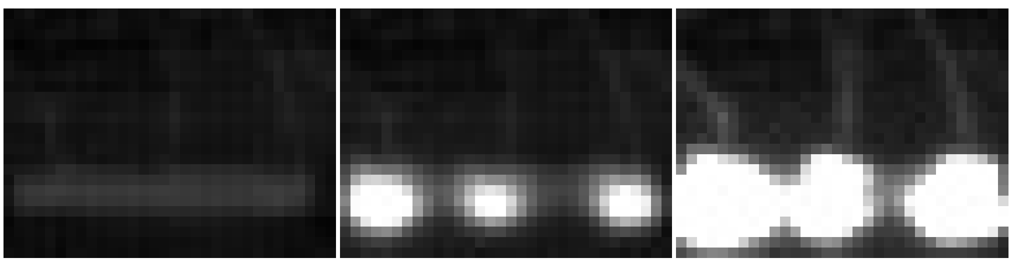

Fig. 8 Successive video frames for shot 3 at 0, 5, and 10 μs (left to right)

Figure 9 is a diagram of the transfer box configuration used for shots 4–7, i.e., for one FS-43 firing system and 9 RP-80 detonators total, with 3 detonators in series on each of 3 parallel legs.

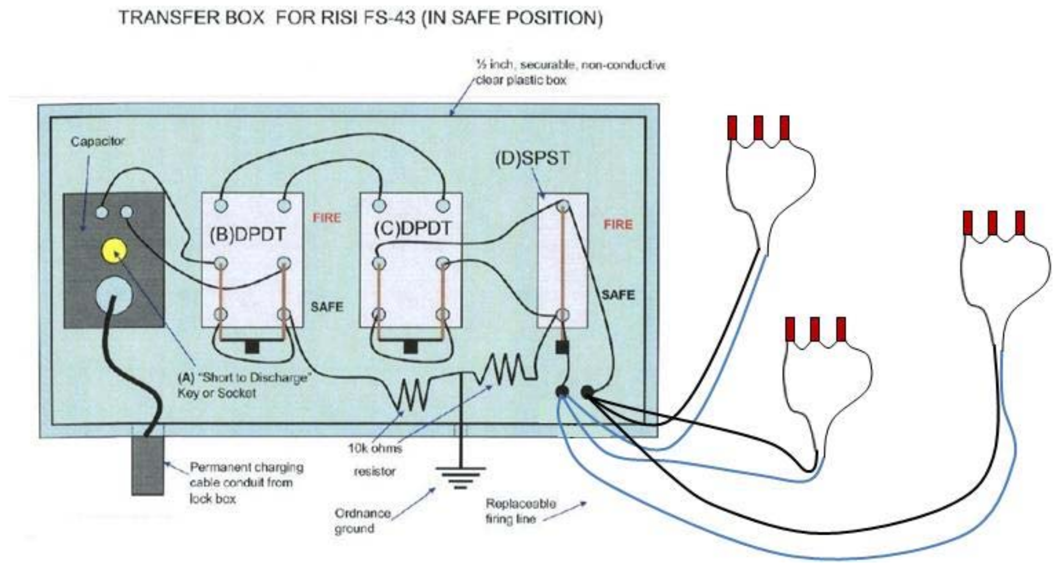

Fig. 9 Transfer box configuration for shots 4–7

Shots 4 and 5 both failed to function as desired. The detonators for shot 4 were arranged in a 3-× 4-inch area to retain the same camera field of view as previous shots. With the detonators in such close proximity, the same high-speed camera settings as the previous shot proved inadequate to visually determine if all detonators initiated within a 5-μs interval. However, postshot inspection of the test site indicated that the detonators on 1 of the 3 parallel legs had been thrown from the immediate area. This suggested that predetonation interference had occurred.

Shot 5 used the same circuit configuration as shot 4, but with 2 minor setup alterations. First, the detonators were separated from each other by several inches to eliminate the suspected predetonation interference. Second, the camera view was enlarged and resolution increased. Figure 10 shows 3 successive video frames (0, 9, and 18 μs) for shot 5. While the 9-μs frame interval was too large to conclusively determine if the 5-μs simultaneity requirement was strictly satisfied, the second and third frames showed disparities in detonation initiation and progression that indicated questionable simultaneity.

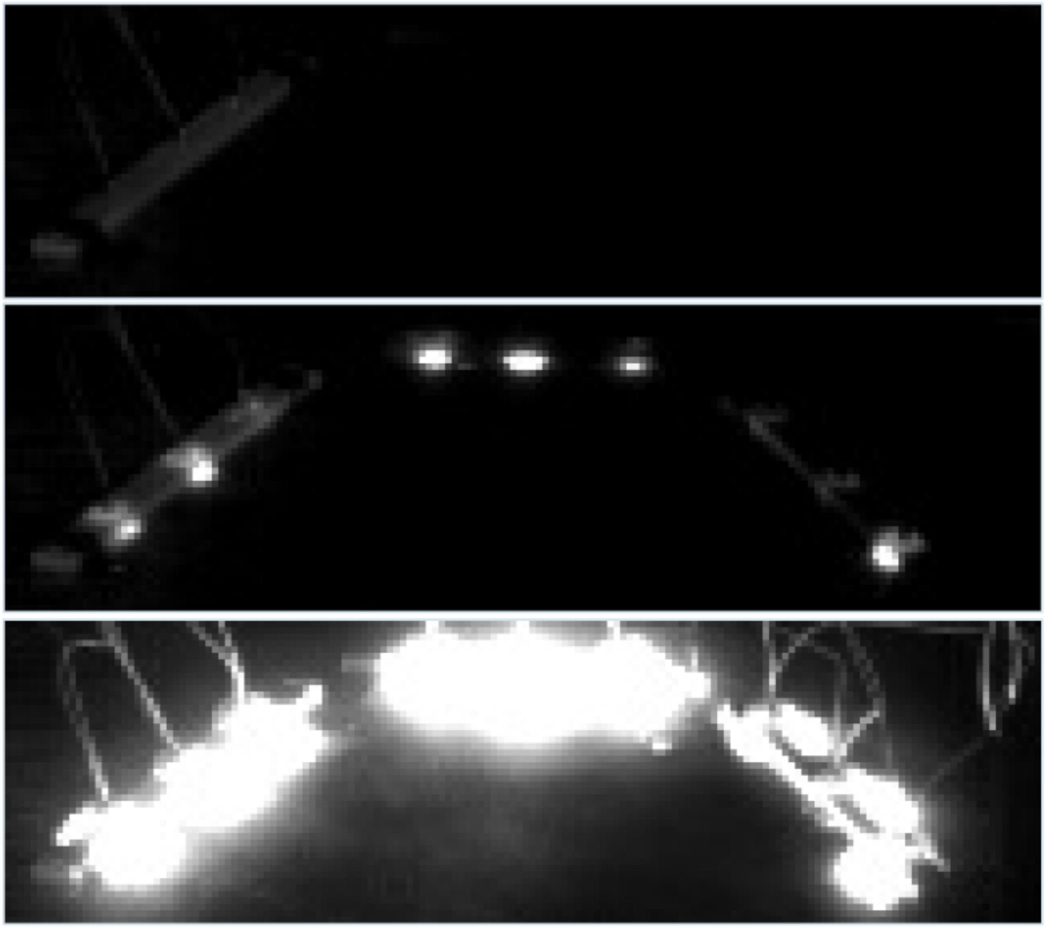

Fig. 10 Successive video frames for shot 5 at 0, 9, and 18 μs (top to bottom)

Shot 6 addressed the initiation disparities observed in shots 4 and 5 by replacing the RG58 cable with the B/W twisted pair wire. Two negative aspects of the RG58 cable were cited: 1) that the larger resistance of the RG58 cable could produce a voltage drop too large for the circuit configuration, and 2) that differences between the geometries and properties of the inner and outer conductors of the RG58 cable could produce voltage anomalies. Prior to shot 6, the camera interval was reduced to 7 μs. Figure 11 shows 4 successive video frames (0, 6.25, 12.5, and 18.75 μs) for shot 6 demonstrating that all 9 detonators initiated within a 6.25-μs interval and had similar progression. While the 6.25-μs video frame interval was, strictly speaking, larger than the 5-μs interval simultaneity requirement, the observed simultaneity and progression provided by the video was consistent enough to conclude that the 5-μs simultaneity requirement was satisfied.

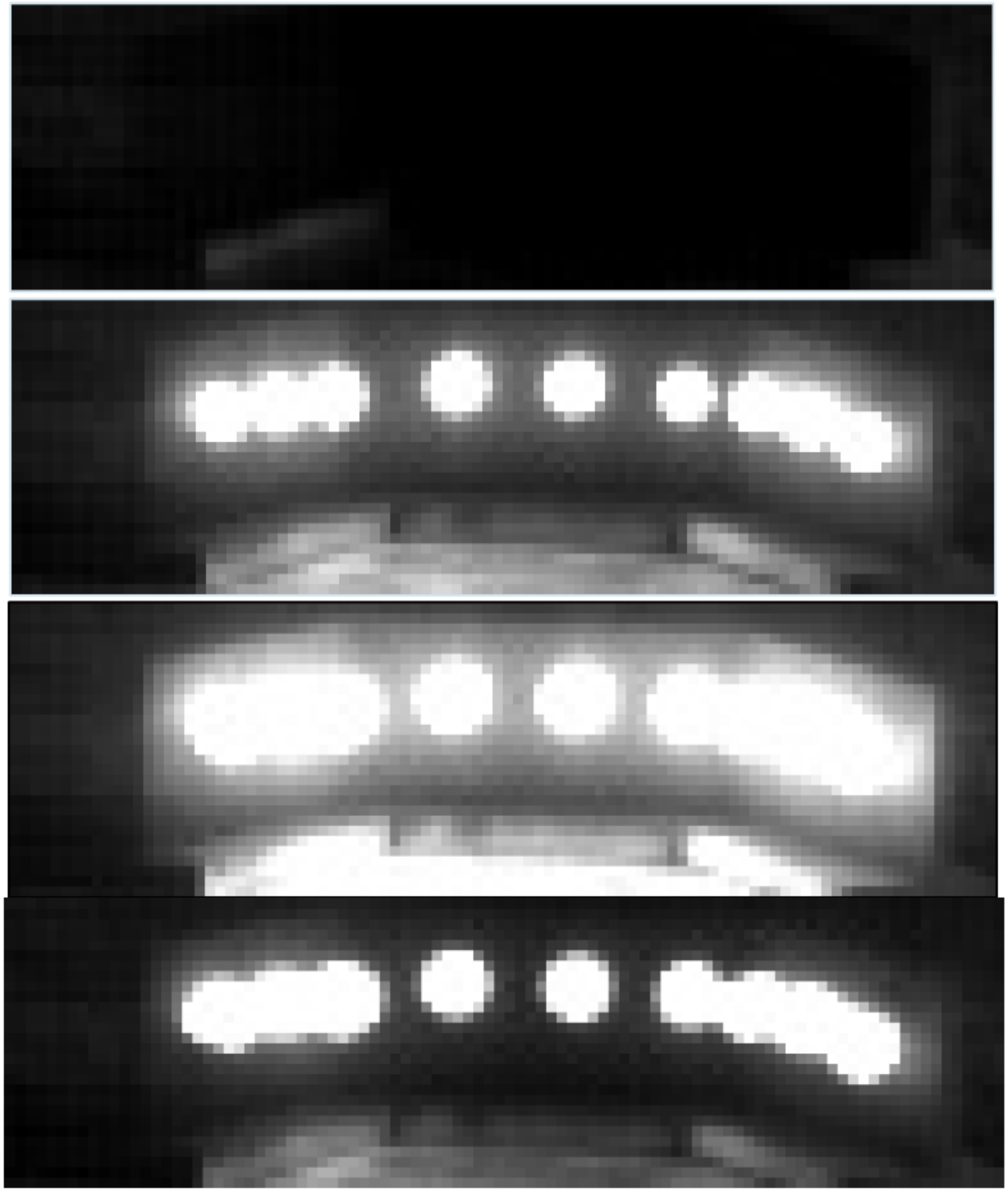

Fig. 11 Successive video frames shot 6 at 0, 6.25, 12.5, and 18.75 μs (top to bottom)

This sequence of video frames for shot 6 also demonstrates that the maximum visible light occurred in the third frame. With the particular camera settings for shot 6, the maximum visible light produced by the detonators occurred at 12.5 ± 6.25 μs. This aspect of the progression of visible light was consistent throughout the set of experiments.

Shot 7 was a virtual repeat of shot 6 in terms of setup and performance, and the B/W twisted pair wire was adopted as the firing line of choice throughout the remainder of the detonator-only experiments as well as the modular charge shot.

Figure 12 is a diagram of the transfer box configuration used for shots 8 and 9, i.e., for one FS-43 firing system and 18 RP-80 detonators total, with 6 detonators in series on each of 3 parallel legs. Figure 13 shows 4 successive video frames (0, 6.25, 12.5, and 18.75 μs) for shot 8 demonstrating that all 18 detonators initiated within a 6.25-μs interval and had similar progression. Shot 9 was a virtual repeat of shot 8 in terms of setup and performance.

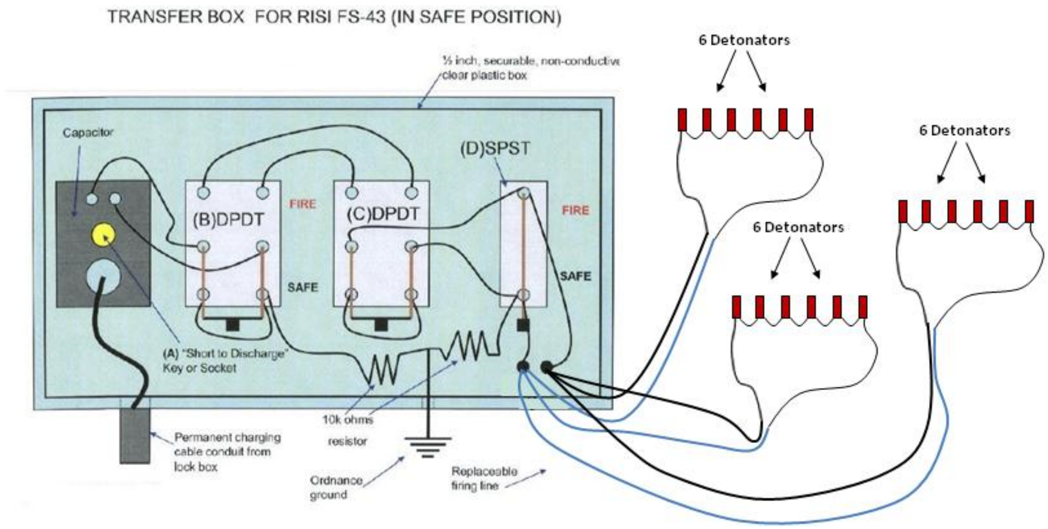

Fig. 12 Transfer box configuration for shots 8 and 9

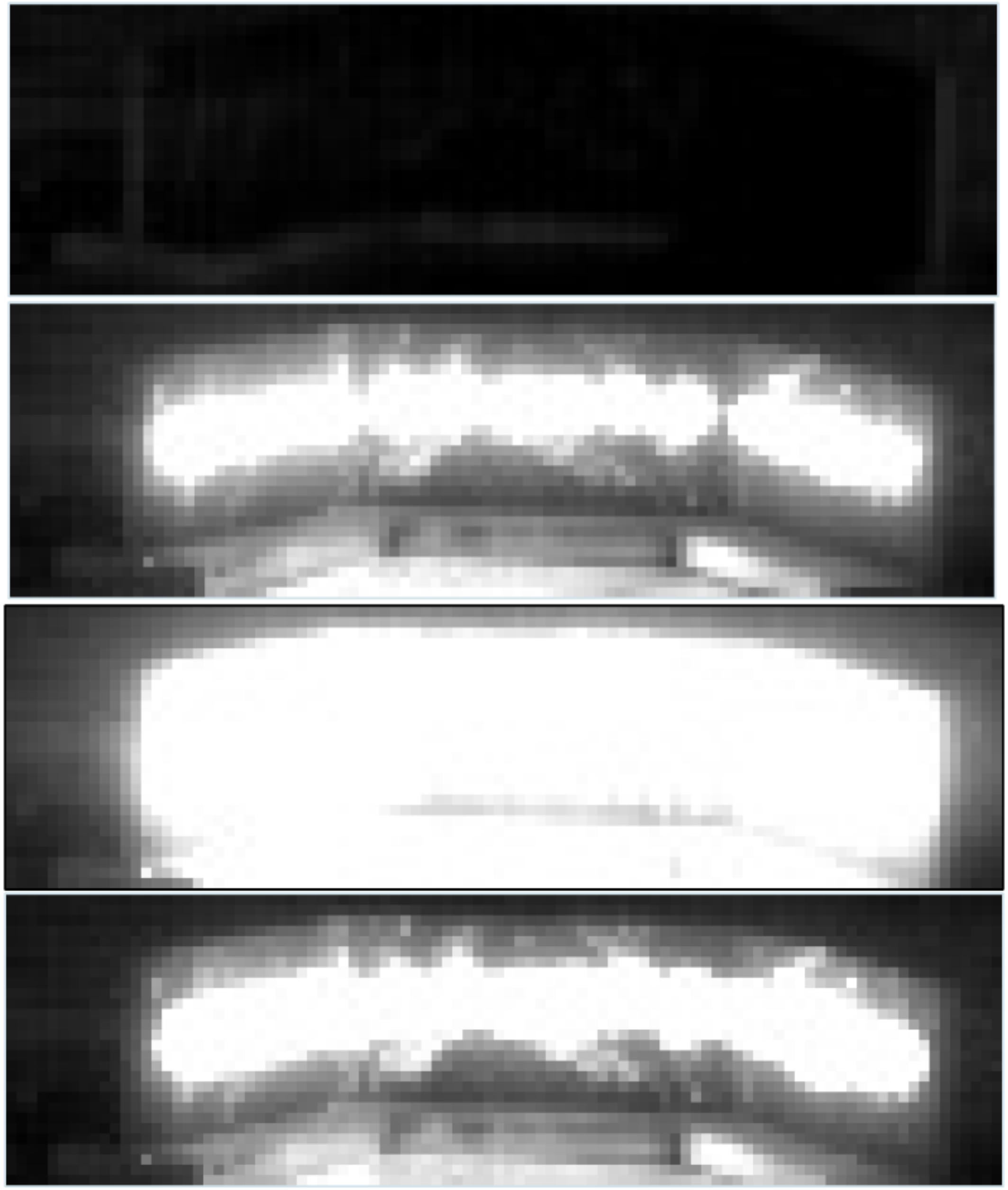

Fig. 13 Successive video frames for shot 8 at 0, 6.25, 12.5, and 18.75 µs (top to bottom)

5. Experimental Results for 2 Separate Firing Systems

Shot 10 and all subsequent shots used 2 separate FS-43 firing systems in the initiation circuit. Shot 10 had 6 detonators total, with each of the 2 FS-43 firing systems having 3 detonators, and with each detonator connected to a parallel leg of B/W twisted pair wire. For shot 10, a Special Systems Inc 5-stage programmer was used to send an initiating pulse to both FS-43 control units. The camera position and settings were unchanged from the previous shot. The 4 successive video frames (0, 6.25, 12.5, and 18.75 µs) for shot 10 (Fig. 14) indicate that all 6 detonators initiated but that the 2 subcircuits (each associated with each of the 2 FS-43 firing systems) were out of synchronization by several microseconds. Shot 11 was a virtual repeat of shot 10 and verified the synchronization disparity between the 2 subcircuits.

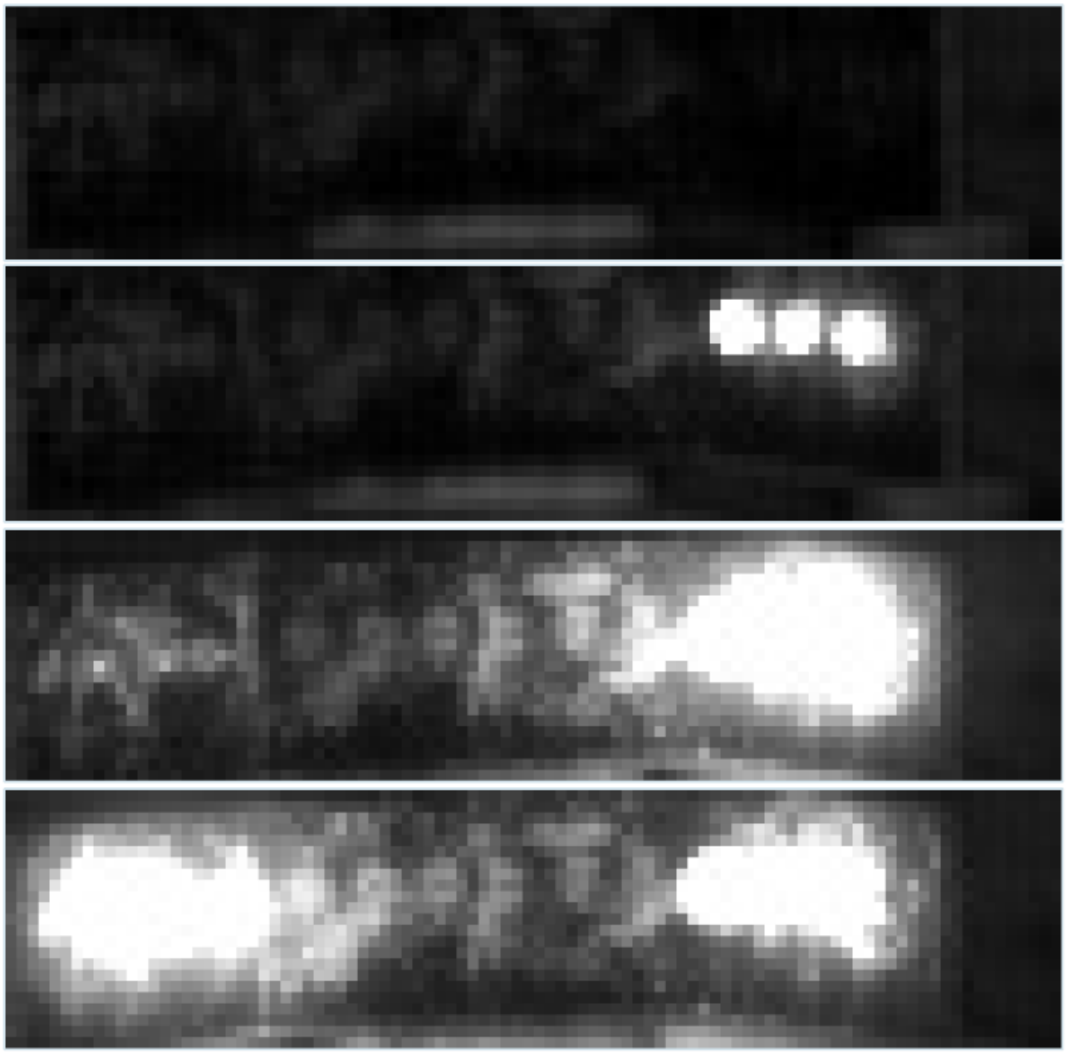

Fig. 14 Successive video frames for shot 10 at 0, 6, 12, and 18 µs (top to bottom)

For the previous shots, the 5-stage programmer had been set up with open contacts that would close upon receiving the command input. Each of the FS-43 control units had been connected to separate contacts within the 5-stage programmer. It was suspected that the 2 contact closures in the 5-stage programmer (one for each of the 2 subcircuits) did not close within the 5-µs simultaneity requirement.

To achieve improved simultaneity between the 2 subcircuits, a modification to the initiation circuit for subsequent shots was adopted as follows. The 5-stage programmer output was moved to the closed contact connector, which operates by opening the contact upon receiving the command input. This connector was connected to a 50-VDC break box, which upon receiving the open circuit would output a single pulse. The single pulse was subsequently split and sent to each of the 2 FS-43 control units.

This modified initiation circuit was evaluated in shot 12 by connecting only one firing line with one detonator to each FS-43 firing system. Figure 15 shows 4 successive video frames (0, 6.25, 12.5, and 18.75 μs) for shot 12 demonstrating that both detonators initiated within a 6.25-μs interval and had similar progression. All subsequent shots used this modified initiation circuit.

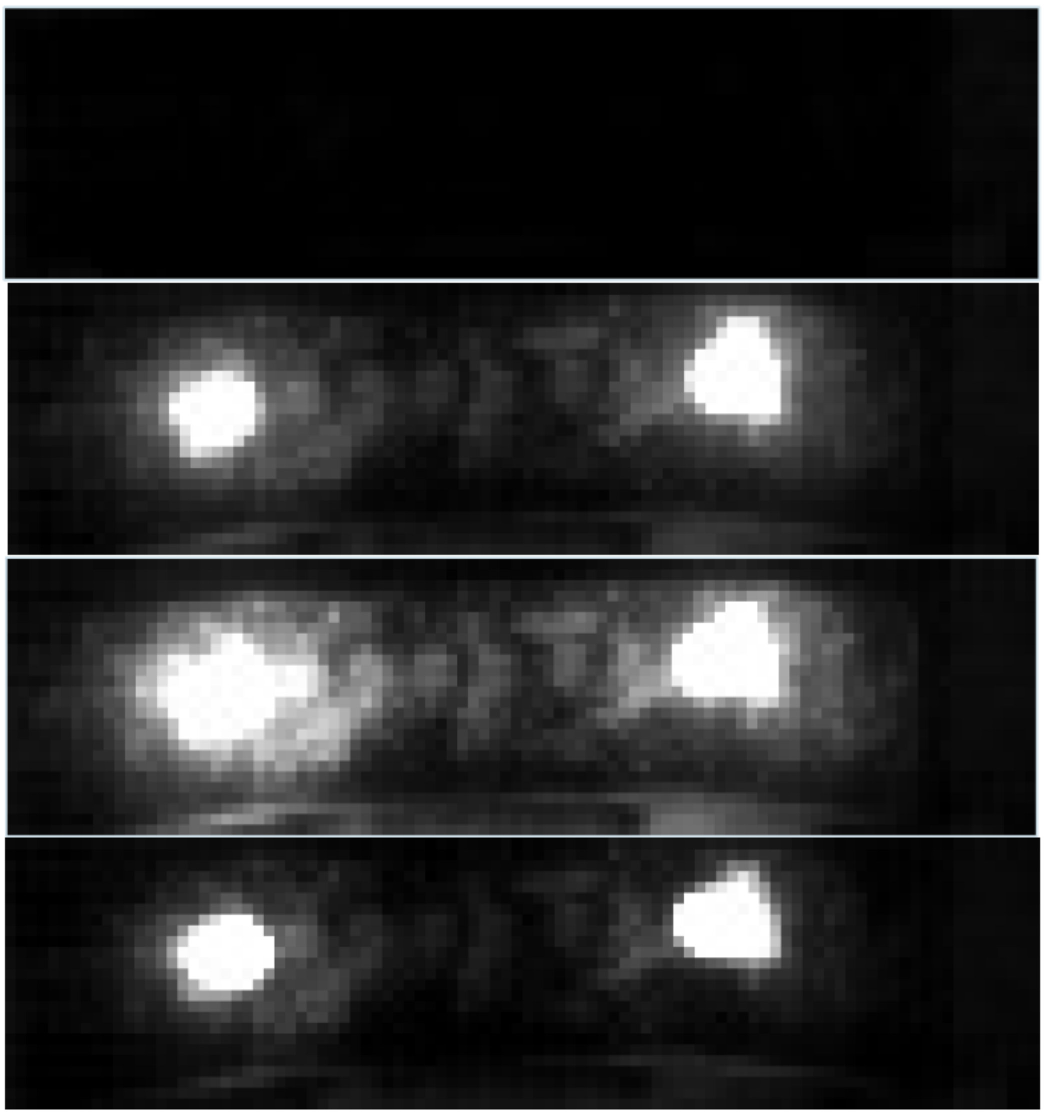

Fig. 15 Successive video frames for shot 12 at 0, 6.25, 12.5, and 18.75 μs (top to bottom)

Shot 13 used the break box and 6 detonators total, with each of the 2 FS-43 firing systems having 3 detonators, and with each detonator connected to a parallel leg of B/W twisted pair wire. The circuit was the same as shots 10 and 11 but with the break box added. The 4 successive video frames (0, 6.25, 12.5, and 18.75 µs) for shot 13 in Fig. 16 indicate that all 6 detonators initiated within a 6.25-µs interval and had similar progression.

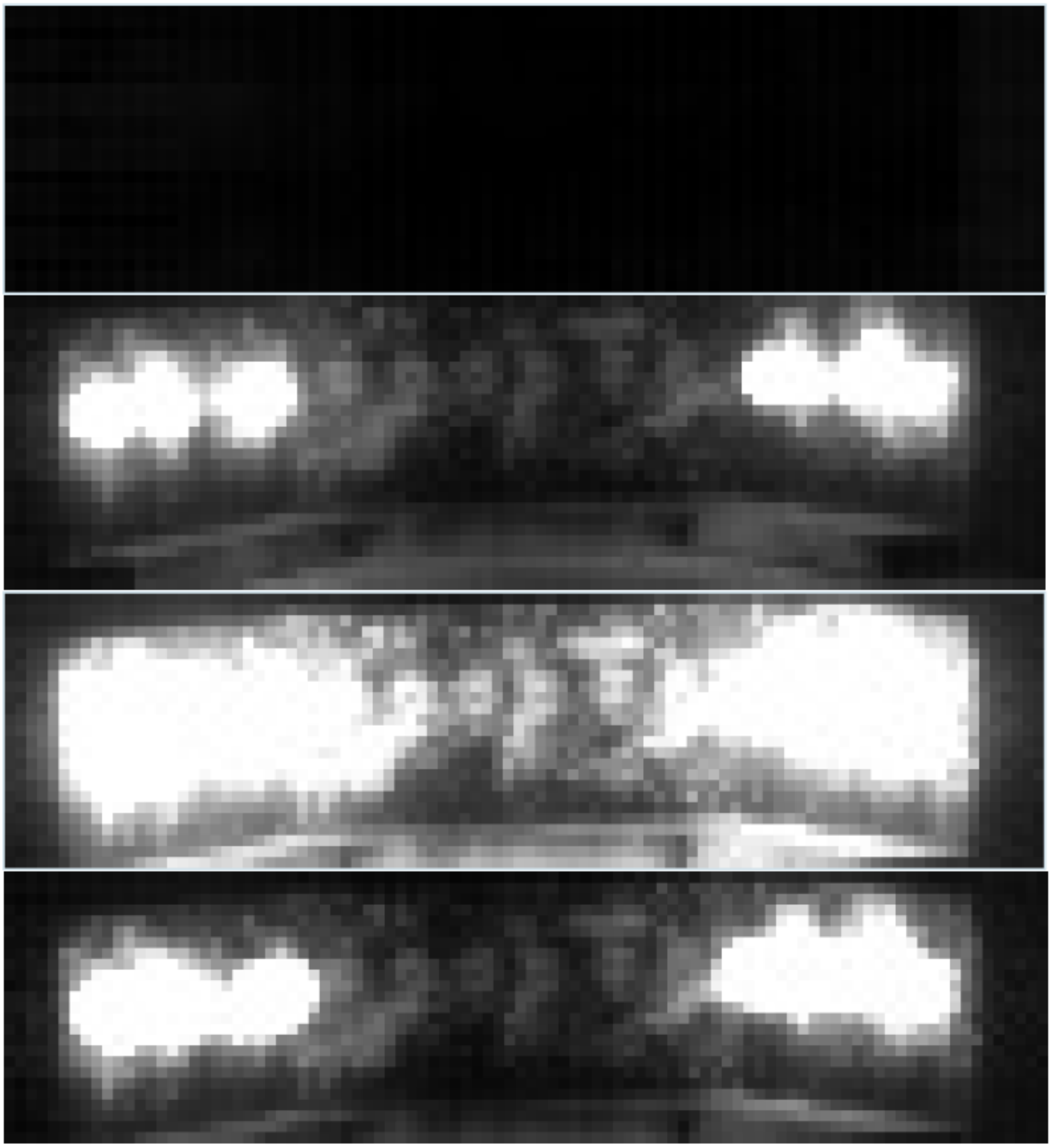

Fig. 16 Successive video frames for shot 13 at 0, 6.25, 12.5, and 18.75 µs (top to bottom)

Shot 14 used the break box and 18 detonators total, with each of the 2 FS-43 firing systems having 3 parallel legs of B/W twisted pair wire, and with each leg having 3 detonators. Each of the 2 subcircuits was the same as shots 6 and 7. The 4 successive video frames (0, 6.25, 12.5, and 18.75 μs) for shot 14 in Fig. 17 indicate that all 18 detonators initiated within a 6.25-μs interval and had similar progression.

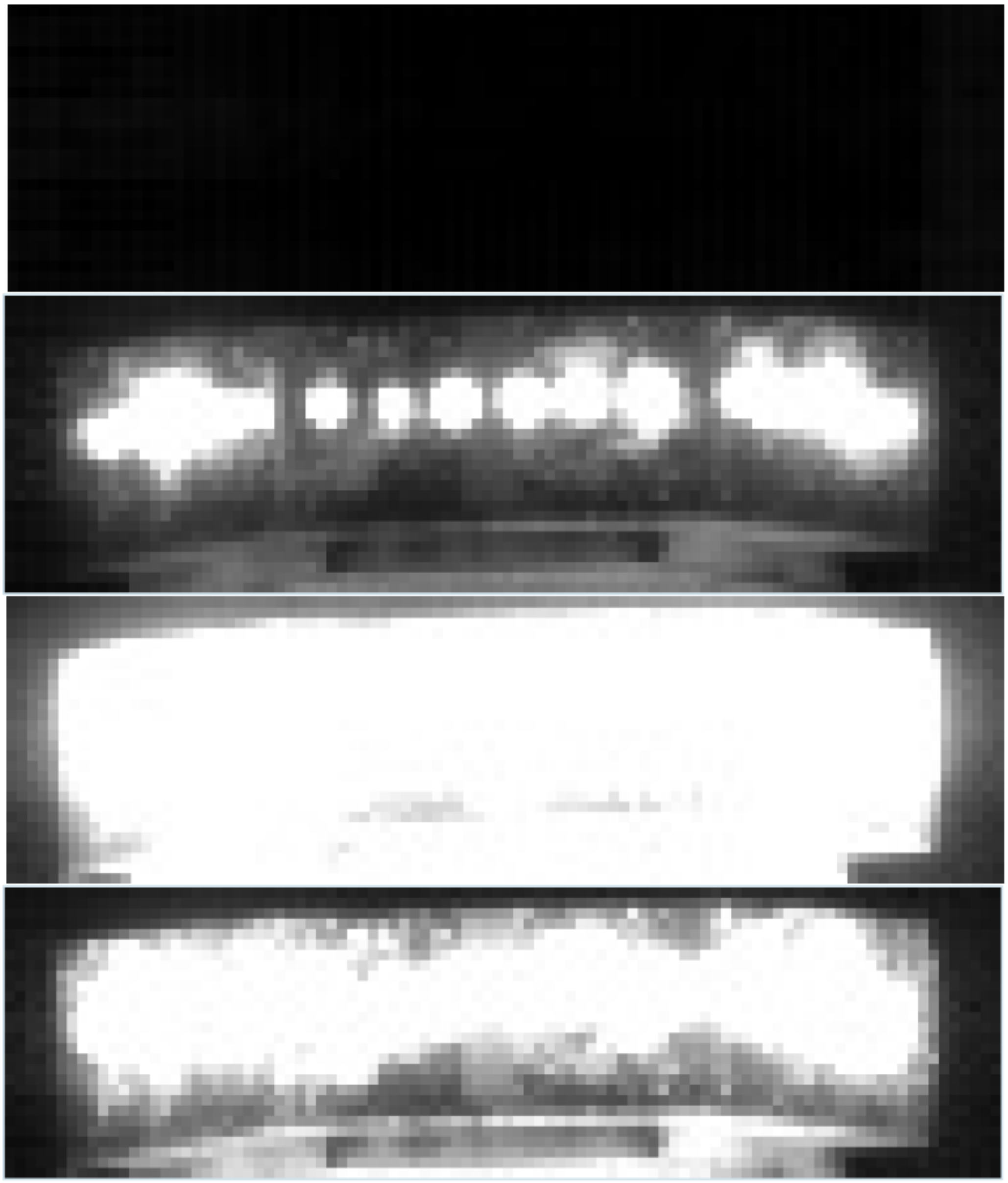

Fig. 17 Successive video frames for shot 14 at 0, 6.25, 12.5, and 18.75 μs (top to bottom)

Shot 15 used the break box and 36 detonators total, with each of the 2 FS-43 firing systems having 3 parallel legs of B/W twisted pair wire and with each leg having 6 detonators. After the shot, it was realized that the break box had not been turned on. Figure 18 shows 4 successive video frames (0, 6.25, 12.5, and 18.75 µs) for shot 15. The top 18 detonators, which were connected to one FS-43 firing system, initiated several microseconds before the bottom 18 detonators, which were connected to the other FS-43 firing system.

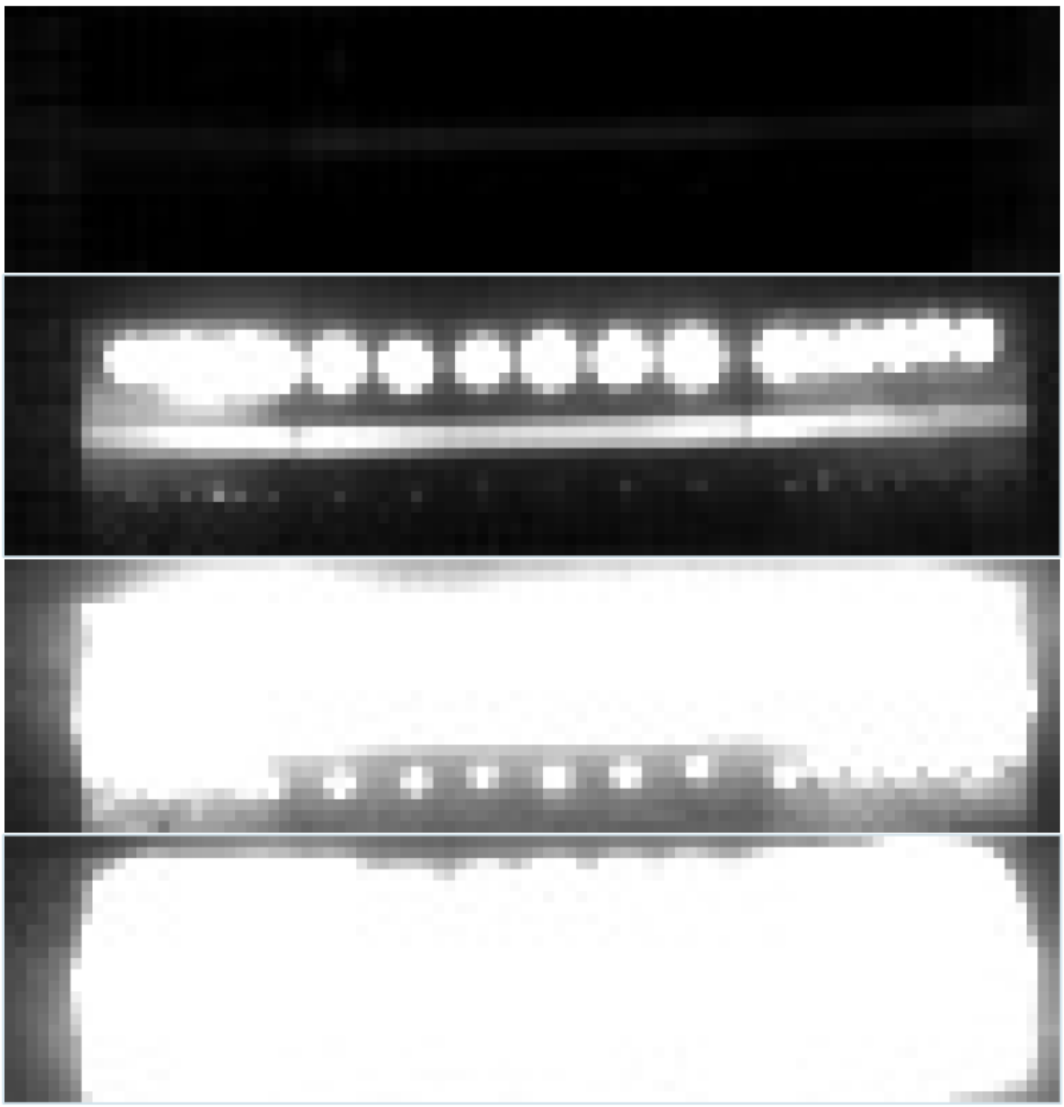

Fig. 18 Successive video frames for shot 15 at 0, 6.25, 12.5, and 18.75 µs (top to bottom)

Shot 16 was repeat of shot 15 except that the break box was turned on. The 4 successive video frames (0, 6.25, 12.5, and 18.75 μs) for shot 16 in Fig. 19 indicate that all 36 detonators initiated within a 6.25-μs interval and had similar progression.

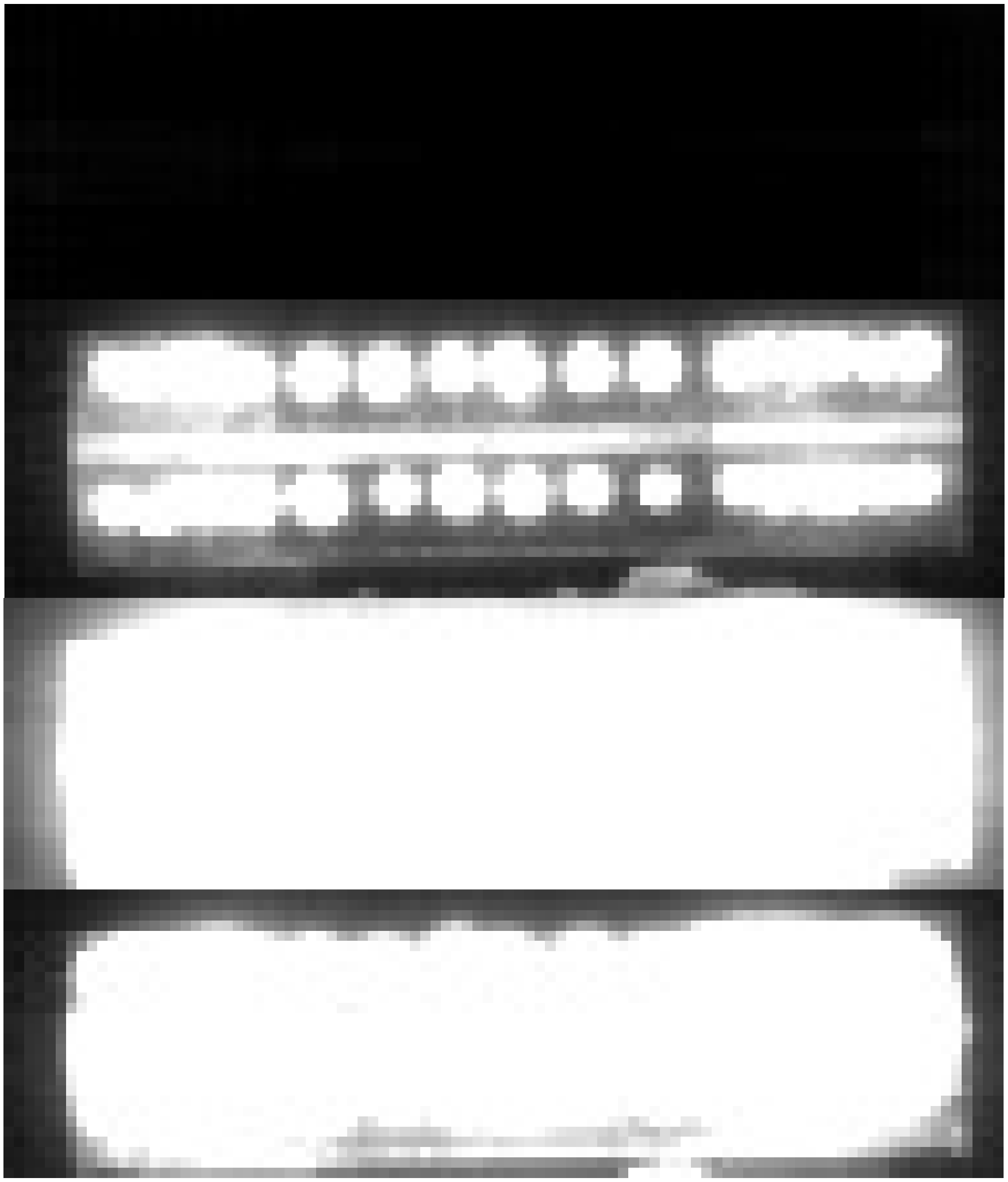

Fig. 19 Successive video frames for shot 16 at 0, 6.25, 12.5, and 18.75 μs (top to bottom)

The 16 shots consisting of up to 36 detonators provided the verification of reliability and simultaneity needed to proceed with the 33 Comp B modular charge shot. Several other Comp B modular charge shots, using up to 7 charges connected in series on a single leg, were also conducted early in the program. Those shots demonstrated, among other things, that the Comp B modular charges could be initiated using RP-80 detonators without a booster pellet.

Figures 20 and 21 show 2 views of the 33 Comp B modular charge setup. The postshot results indicated that a successful simultaneous detonation of 33 Comp B modular charges in close proximity was achieved.

Fig. 20 Side view of 33 Comp B modular charge setup. (Photograph courtesy of Dr Muge Fermen-Coker.)

Fig. 21 Top view of 33 Comp B modular charge setup. (Photograph courtesy of Dr Muge Fermen-Coker.)

6. Conclusions

The detonator-only experiments, along with the associated investigation into the required parameters, demonstrated an in-house capability for initiating 36 detonators within a 5-μs simultaneity interval. Relevant details concerning the setup of the initiation circuit were encountered during the process and contributed to the knowledge base. Those details included not only those aspects that contributed to successful application of the technology, but also those aspects that demonstrated inherent limitations. Perhaps most importantly, the experiments served to reaffirm the importance of establishing baseline characteristics on explosive operations such as simultaneous detonations, serving as a model for future experiments to be conducted safely and on a repetitive basis.

7. References

1. ARL Standard Operating Procedure 385-008. Static detonation of high explosives (outdoor facilities). Aberdeen Proving Ground (MD): Army Research Laboratory (US), 2009 Mar 3.

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Appendix A. Manufacturer-Supplied Information Sheet on the FS-43

This appendix appears in its original form, without editorial change.

FS-43 Firing System

DESCRIPTION

The FS-43 EBW Firing System is designed for field firings where the actual module voltage must be monitored and instantaneous firing is required and AC power is available. The separate module allows long distance and remote firings to be performed. The system includes a Control Unit (P/N 188-7238) and a Firing Module (P/N 188-7096).

DESIGN AND SPECIFICATIONS

Input Energy

- 110 VAC standard
- 220 VAC available

Output Energy

- 4000 volt pulse with 1500 amperes peak current into low resistance load. (8.0 joules)

Circuit

- DC to DC converter with high voltage energy
- Triggered gap for instantaneous firing (less than 10 microseconds)
- Meter in Control Unit to monitor voltage
- External or manual trigger.
- Trigger monitor
- Remote arming

Control Unit Input Connection

- U.S. Type, 3-pin plug for 110 VAC

Control Unit

- Safety Interlock Connector
- Sealed Arm Switch with indicator light
- Adjustment for long control cables
- Three-pin plug for 110 VAC
- Meter to indicate module arm voltage and discharge rate
- Six-pin connector to module
- Three-pin connector for remote arm
- BNC connector for external trigger In and Out
- Short circuit protected
- External dimensions: 19" x 5" x 13"

Control Unit to Module Connection

- Requires 3-pair shielded cable
- Maximum 10,000 feet of 20 gauge wire

Module

- Six-pin connector for connection from Control Unit
- Safety interlock connector
- Five-way binding post output terminals

Module to Detonator Connection

- Maximum 100 feet twin lead blasting wire, P/N 167-8559 or 300 feet maximum Type 'C' coaxial cable, P/N 167-2669

Caution: While EBW and EFI Initiators are inherently less susceptible to accidental detonation during handling and set-up than devices containing primary explosives, electrical and electronic firing systems are sensitive to transient electrical energies which could cause premature triggering or firing. The blasting area must be clear of personnel and equipment before the detonator leads are connected to any RISI Firing System. Only approved RISI Firing Systems should ever be used to initiate or detonate any explosive product manufactured and authorized for sale by RISI.

FS-43 Operation Discussion

The purpose of the FS-43 Control Unit is to provide low voltage electrical energy to the Firing Module and to ensure a safe and reliable operation sequence for the firing of EBW detonators.

The output from the Control Unit to the Firing Module is 40 to 120 volts. This output occurs when the "Arm" switch is held in the "Arm" position and the shorting plug is mated into the Control Unit "Safety Interlock" connection. When the system is armed, the "Firing Volts" meter will read the high voltage from the Firing Module. The "Line Adjust" knob is then used to adjust the firing voltage to 4000 volts before firing is initiated. When the "Fire" button is pressed or an external pulse is applied to the "Accessary" connection, detonation will typically occur within 10 microseconds ($10x10^{-6}$). Should the operator wish to abort firing while arming is taking place, simply release the "Arm" switch.

The purpose of the FS-43 Firing Module is to provide a significant amount of flexibility to this EBW detonator firing system. Since the firing pulse to function the EBW detonator must be applied at the proper rate of rise, or frequency, the firing module must be placed relatively close to the detonator. By being able to separate the Firing Module from the control unit, the operator can perform the detonation at extended distances as required by the size and characteristics of the main explosive charge.

The input charge to the Firing Module must be between 32 and 40 volts. This low voltage input is applied to the input connector which charges a one microfarad capacitor. When this capacitor reaches 4000 volts, the Firing Module is ready to be fired. Triggering of the triggered spark gap occurs by applying a 30 volt pulse to the input connector. This discharges the one microfarad capacitor into the yellow terminals which, if properly connected, will fire the EBW detonator. Detonation will occur in less than 10 microseconds from the time that the 30 volt pulse is applied.

By mating the shorting plug to the "Discharge" connector, the energy storage capacitor is completely and immediately discharged thus precluding inadvertent arming of the firing module and detonation of the EBW detonator.

Caution: While EBW and EFI Initiators are inherently less susceptible to accidental detonation during handling and set-up than devices containing primary explosives, electrical and electronic firing systems are sensitive to transient electrical energies which could cause premature triggering or firing. The blasting area must be clear of personnel and equipment before the detonator leads are connected to any RISI Firing System. Only approved RISI Firing Systems should ever be used to initiate or detonate any explosive product manufactured and authorized for sale by RISI.

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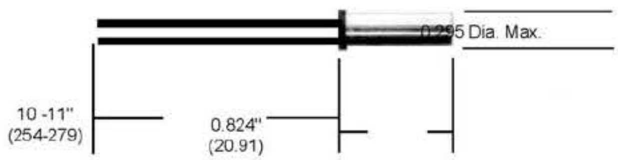
Appendix B. Manufacturer-Supplied Information Sheet on the RP-80

This appendix appears in its original form, without editorial change.

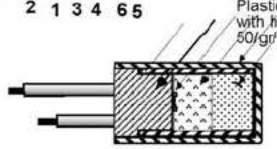
RP-80 EBW Detonator

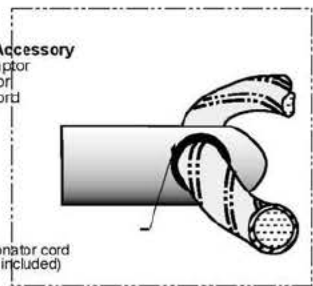
P/N 188-7042

The RP-80 detonator is a standard end lighting detonator. It is housed in an aluninum cup to provide sealing and strength to the explosive charge. It can be purchased without the cup as P/N 167- 9964. It is capable of detonating compressed TNT and other similar explosives.



RP-80 Explosive Train





1. Plastic molded head
2. Brass sleeve
3. Bridgewire (Gold)
4. Initiating explosive: 80 mg PETN
5. Output explosive: 123 mg RDX
6. Aluminum cup 0.007 " thick

RP-80 Firing Parameters

• Threshold Burst Current:	180 amps
• Threshold Voltage:	Approx. 500 volts
• Threshold Voltage Std. Deviation:	75 volts maximum
• Function Time:	2.65 µsec. typical
• Function Time Simultaneity Standard Deviation:	0.125 µsec Max.

Caution: While EBW and EFI Initiators are inherently less susceptible to accidental detonation during handling and set-up than devices containing primary explosives, electrical and electronic firing systems are sensitive to transient electrical energies which could cause premature triggering or firing. The blasting area must be clear of personnel and equipment before the detonator leads are connected to any RISI Firing System. Only approved RISI Firing Systems should ever be used to initiate or detonate any explosive product manufactured and authorized for sale by RISI.

Appendix C. Manufacturer-Supplied Chart and Discussion Points regarding Series-Parallel Firing of EBW Detonators

This appendix appears in its original form, without editorial change.

SERIES PARALLEL FIRING OF EBW DETONATORS

It is possible to function more than one EBW detonator from a single firing module by wiring the detonators in various parallel-series combinations. The following table shows the number of detonators that can be fired on each leg of a series-parallel circuit from the RISI FS-10, FS-17 or FS-43 fireset.

	Number of Parallel Legs							
Feet of Blasting Wire	1	2	3	4	5	6	7	8
25	10	9	8	7	6	5	4	3
50	8	7	6	5	4	3		
75	6	5	4	3				
100	4	3						

For example, with 50 feet of blasting wire (P/N 167-8559), 6 detonators can be placed at the end of each leg of 3 parallel legs for a total of 18 detonators per shot. If greater firing distances are required, RISI "C" cable (P/N 162-2669) can be substituted for the blasting wire on a three to one ratio i.e., 300 feet of "C" cable is equivalent to 100 feet of blasting wire.

Some precautions that should be observed are:

Each parallel leg should have approximately the same circuit characteristics.

Different model detonators should not be used on the same test.

Excessive cable lengths between the detonators on a series string should be avoided.

All parallel legs MUST terminate at the Firing Module. No trunk cable.

Before performing a "crucial" experiment, a trial shot should be performed with CVR's or CVT's to determine whether there is sufficient current for this many detonators. If this equipment is not available, a trial firing with one more detonator or firing leg than is planned for the actual experiment will generally assure an adequate safety factor.

List of Symbols, Abbreviations, and Acronyms

ARL	US Army Research Laboratory
AWG	American gauge wire
B/W	black and white
EBW	exploding bridge wire
SOP	Standard Operating Procedure
TEF	Transonic Experimental Facility

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